

PATENT US 10/716,415
Atty Dkt: 034044.028

REMARKS

The Office action mailed 7 February 2006, has been received and its contents carefully noted. The pending claims, claims 1-29, were rejected. By this amendment, claims 1, 3, 11, 18, and 23 have been amended. Support may be found in the specification and the claims as originally filed. No statutory new matter has been added. Therefore, reconsideration and entry of the claims as amended are respectfully requested.

Interview of 2 March 2006

Applicants greatly appreciate the Examiner and the Examiner's supervisor taking the time to conduct a personal interview on 2 March 2006.

During the interview, Applicants' representative explained that the prior art does not teach or suggest multilayer polymer-quantum dot light emitting diodes (PQD-LEDs) which are made by consecutively spinning layers of materials, wherein each layer has a solubility that is different from the layer upon which it is spun, e.g. aqueous soluble layer spun coated upon an organic (or polymer) soluble layer or an organic (or polymer) soluble layer spun coated upon an aqueous soluble layer.

The prior art never contemplated making multilayer PQD-LEDs by consecutively spinning layers of materials wherein the layer being spun has a different solubility from the previous layer. Thus, the prior art multilayer PQD-LEDs having spun coat layers suffered from diffusive boundaries between the layers that were caused by mixing between the layers. The mixing at the boundaries between the layers causes problems which include mixing of conductive and emissive species, poor conductivity, charge conduction imbalance, and quenching of emission. Besides diffusion of two layers in a moderate good scenario, the bottom layer can be totally washed off in a more realistic scenario.

The present invention solves these problems by spinning layers of materials, wherein each layer has a solubility that is different from the layer upon which it is spun. Thus, the spun coat layers do not suffer from diffusive boundaries caused by mixing between adjacent layers or the complete removal of the bottom layer. As a result, the process limitations, i.e. "spun coat" layers, are structural parts of the claimed product which should be given patentable weight. See 68 JPTOS 3 (1986) and *In re Luck*, 476 F.2d 650 (CCPA 1973).

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The Examiners agreed to give the process limitations of the claims patentable weight and suggested that the Applicants clearly articulate the differences between the multilayer PQD-LEDs as claimed with those of the prior art.

Prior Art Problems

Prior art LED devices suffer from various problems including "wetting" problems, mixing of conductive and emissive species, washing off the bottom (preceding) layer by spin coating of a top (subsequent) layer owing to similar solubility, poor conductivity, quenching, and the like.

Specifically, spin coating an aqueous layer of any species on an organic polymer layer and then spin coating another organic polymer/molecule layer on top of the second layer does not produce good quality layers due to poor wetting. In fact, Xu et al. disclosed the necessity of a surfactant in order to overcome the wetting problems. *See* Xu et al. (2003) Applied Physics Letts. 83(23):4695-4697 (enclosed herewith). The present invention does not suffer from wetting problems, *i.e.* no surfactant is needed for good quality layers.

The prior art also suffered from processibility issues related to mixing (or complete washing off) of conductive (polymers) and emissive species (QDs) where the conductive and emissive species have similar solubilities, *i.e.* both are soluble in organic solvents. *See*, for example, Coe et al. which describes an LED device made by mixing organic soluble quantum dots with an organic solution of TPD. Coe et al. (2002) Nature 420:800-803 (enclosed herewith). In Coe et al., the QDs phase segregate to the top and then a third layer of organic soluble material is thermally evaporated thereon to give a trilayered structure. Since all layers of Coe et al. are organic soluble, the third layer can not be deposited by spinning without disrupting the quantum dot layer and causing mixing between the two layers or complete washing off of the quantum dot layer. Further, Coe et al. is limited to monolayers of QDs and the suitable QDs employed are limited to specific sizes and chemistries. *See* Chaudhary & Ozkan (2004) Appl. Physics Letts 84(15):2925-2927.

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The Claimed Invention

Applicants respectfully submit that the claims are directed to a multilayer PQD-LED comprising at least one *aqueous soluble* quantum dot layer between a first polymer layer and a *spun coat* second polymer layer or *a first polymer layer and a spun coat* organic molecule layer.

The multilayer PQD-LED as recited in claim 1, comprises *an aqueous soluble* quantum dot layer having a *spun coated* organic soluble layer thereon. Since the adjacent layers are of different solubilities, the aqueous soluble QDs layer are not miscible/soluble in the organic soluble layer spun coated thereon. Consequently, the layer of QDs is uniform and the QDs do not disperse into or mix with the adjacent polymer/organic layers. Thus, the spun coat layers of the claimed invention are different from the prior art in that the spun coat layers are uniform and do not have diffusive boundaries, i.e. mixing between adjacent layers.

The multilayer PQD-LED as recited in claim 18 comprises alternating layers of QDs that are soluble in aqueous solvents and QDs that are soluble in organic solvents. The different solubilities of the QD layers allows a subsequent layer to be evenly spun directly upon the preceding layer, e.g. an organic (polymer) soluble QD layer spun coated on an aqueous soluble QD layer. Since the adjacent layers are of different solubilities, the QDs in one layer are not miscible or soluble in the adjacent layer. As a result, there is no observable mixing of the different QDs in the adjacent layers.

Rejection under 35 U.S.C. 102(e)

In the Office action of 7 March 2006, the Examiner maintained the rejection of claims 1-3, 5-10, 12, 16, 17-21, and 23-26 under 35 U.S.C. 102(e) as being anticipated by Jain et al. (US Patent No. 6,797,412). The Examiner also maintained the rejection of claims 1-3, 5, 6, 12, 13, 16, 17, and 23-26 under 35 U.S.C. 102(e) as being anticipated by Miller et al. (U.S. Patent No. 6,803,719).

Applicants respectfully submit that nowhere does the cited prior art teach or suggest spin coating alternating layers of different solubilities. Specifically, nowhere does the prior art teach or suggest spin coating an organic soluble material on top of an aqueous soluble layer of quantum dots. Instead the prior art (1) spins layers of similar solubilities on top of each other, e.g. organic on top of organic which results in mixing or diffusion or complete washing off of the layer

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between the layers, which results in less discrete layers in the multilayer PQM-LED or (2) "grows" an organic layer on top of the quantum dot layer.

Jain et al.

Jain et al. does not disclose that the layer on the QD layer is a *spun coat* layer. Instead, Jain discloses *growing* a thin layer of the *organic* (organic soluble) material on top of the QD layer. In Jain et al., "grown" likely indicates "thermally evaporated". Thermal evaporation is a high temperature process that is not suitable for depositing a layer on a large surface. Further, thermal evaporation is limited to organic molecules. Jain et al. does not specifically teach that the QDs are aqueous soluble or functionalized to be aqueous soluble. Thus, the QDs may be organic soluble. Since the QDs of Jain et al. may be organic soluble, Jain et al. does not specifically teach or suggest spinning an organic layer on top of the QD layer as spinning a polymer/organic molecule layer on top of the QD layer is problematic since the QD layer would dissolve by and mix with the organic solvents. Thus, Jain et al. does not teach or suggest a *spun coat* polymer layer or organic molecule layer deposited on an *aqueous soluble* quantum dot layer as recited in claim 1.

Further, Jain et al. does not teach or suggest an aqueous soluble QD layer on top of a *polymer layer*. Instead, Jain et al. discloses a QD layer on an *inorganic semiconductor layer*. See e.g. col. 6, lines 1-9. This inorganic semiconductor layer of Jain et al. is not even equivalent to the polymer layer of the claimed invention. In fact, the inorganic semiconductor layer of Jain et al. makes the resulting LED inflexible and rigid, which is unlike the present invention. Consequently Jain et al. does not teach or suggest the invention of claim 1.

Although Jain et al. suggests a LED device having a plurality of adjacent QD layers in the figures, nowhere does Jain et al. teach or suggest that the QD layers have different solubilities such that each layer may be spun coated without having an effect on the preceding layer. Therefore, Jain et al. does not teach or suggest the invention of claim 18.

Since Jain et al. does not disclose (1) an *aqueous soluble* quantum dot layer having (2) a *spun coat* polymer layer or organic molecule layer deposited thereon, Jain et al. does not anticipate the claimed invention. Therefore, the rejection under 35 U.S.C. 102(e) should properly be withdrawn.

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Miller et al.

The Examiner deemed that Miller et al. discloses a multilayer polymer quantum dot light emitting diode comprising at least one quantum dot layer between a first polymer layer and a second polymer layer.

Applicants respectfully submit that like Jain et al., Miller et al. does not disclose a *spun coat* polymer layer or organic molecule layer deposited on an *aqueous soluble* quantum dot layer. Specifically, the quantum dots in Miller et al. are embedded in an insulating polymer matrix. Thus, the QDs of Miller et al. are not aqueous soluble. In fact, the Examiner noted that Miller et al. does not teach or suggest *hydrophilic* (water loving = aqueous soluble) QDs. Thus, the QD layer of Miller et al. is not an *aqueous soluble* QD layer. Miller et al. does not teach or suggest an *aqueous soluble* QD layer.

Further, the LED of Miller et al. is not the same as the electrically driven LED device of the present invention. Specifically, due to the insulating matrix, the design of Miller et al. is not even an electrically driven LED device. Instead, the device of Miller et al. is a light driven LED wherein another light source is necessary to produce light. Thus, the light driven LED device of Miller et al. does not anticipate the electrically driven LED device of the present invention.

Applicants also submit that Miller et al. does not disclose a *spun coat* polymer or organic molecule layer on top of the QD layer. In fact, as discussed above, spinning a polymer layer on top of the QDs embedded *polymer* layer would result in mixing between the two layers because of the similar solubilities. Consequently, Miller et al. does not teach or suggest a *spun coat* polymer or organic molecule layer on top of the QD layer.

Since Miller et al. does not teach or suggest (1) an *aqueous soluble* QD layer having (2) a *spun coat* polymer or organic molecule layer on top of the QD layer, Miller et al. does not anticipate the claimed invention. Therefore, the rejection under 35 U.S.C. 102(e) should properly be withdrawn.

Rejection under 35 U.S.C. 103(a)

The Examiner maintained the claim rejections under 35 U.S.C. 103(a) as being unpatentable over Jain or Miller and further in view of Coombs et al. (U.S. Patent No. 6,572,784)

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and in view of Matsuo et al. (U.S. Patent No. 6,391,482), Bawendi et al. (U.S. Patent No. 6,444,143), or Dumbrow et al. (U.S. Patent No. 6,475,364).

As explained above, the claimed invention is directed to a multilayer polymer-quantum dot light emitting diode comprising at least one (1) *aqueous soluble* quantum dot layer between a first polymer layer and (2) a *spun coat* second polymer layer or *a first polymer layer and a spun coat* organic molecule layer. The various combinations of the prior art cited by the Examiner do not alleviate the deficiencies of Jain or Miller. None of the combinations discloses or suggests an *aqueous soluble* quantum dot layer having a *spun coat* polymer layer or organic molecule layer deposited thereon.

Therefore, the present invention as claimed is nonobvious and the rejection under 35 U.S.C. 103(a) should properly be withdrawn.

Request for Interview

Applicants respectfully request either a telephonic or an in-person interview should there be any remaining issues.

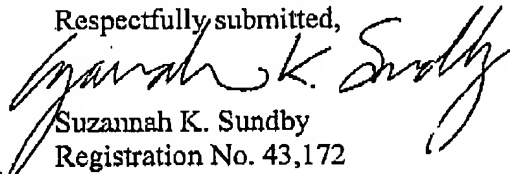
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CONCLUSION

All of the stated grounds of objection and rejection have been properly traversed, accommodated, or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently outstanding objections and rejections and that they be withdrawn. It is believed that a full and complete response has been made to the outstanding Office Action and, as such, the present application is in condition for allowance. If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided.

It is not believed that extensions of time are required, beyond those that may otherwise be provided for in accompanying documents. However, in the event that additional extensions of time are necessary to prevent abandonment of this application, then such extensions of time are hereby petitioned under 37 C.F.R. §1.136(a), and any fees required therefor are hereby authorized to be charged to **Deposit Account No. 02-4300**, Attorney Docket No. **034044.028**.

Respectfully submitted,



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